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Discusses deliberations of a 6 weeks' curriculum study at Harvey Mudd College in 1958. Two committees considered separately the engineering curriculum on the one hand, and the humanities-social science curriculum, on the other. "The purpose of the study was not only to make recommendations regarding college's curriculum but also to consider the larger issues behind the education of the mid-20th-century scientist-engineer." Participants in the study, numbering about 20, represented a variety of fields and institutions and a wide range of experience.

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SCIENCE AND ENGINEERING

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INTRODUCTION

In the summer following its first academic year, Harvey Mudd College of Science and Engineering invited a number of educators to meet with its faculty for a six-week curriculum study. The purpose of the study was not only to make recommendations regarding the College's curriculum but also to consider the larger issues behind the education of the mid-twentieth century scientist-engineer.

The Fund for the Advancement of Education, in providing a grant for the curriculum study, commented on the College's opportunity to play a distinctive role in American education. As the first college of science and engineering to be founded in this country for three decades, Harvey Mudd is in a singular position to make new departures. Like the experimental colleges of the 1930s, it could have considerable influence in shaping American educational philosophy and methods.

The reports which follow provide an abstract of six weeks' deliberation by some twenty participants, representing a variety of fields and institutions and a wide range of experience. They met in general sessions or committee meetings, according to no pre-ordained plan but depending simply on the trend of discussion and the members on hand at a given moment. The two committees considered separately, but with considerable cross-pollination, the engineering curriculum on the one hand and the humanities-social science curriculum on the other. On July 29 each committee produced a preliminary report. The two reports then served as a basis for an exhaustive review held on August 6.

The August 6 Review presented a rationale for the curriculum to outside observers, including trustees who had originally formulated the College's educational policy and prominent men in science and engineering who were in a position to judge the wisdom and practicality of the proposals. The final report of August 9 incorporated the conclusions of August 6 and the few remaining days of the conference in an attempt to integrate the various proposals while making some fairly specific recommendations for the curriculum.

THE PURPOSE OF THE SUMMER CURRICULUM STUDY

JOSEPH B. PLATT

I welcome you to the review of the summer study which has occupied us over the last six weeks at Harvey Mudd College. Those of us who have participated in the study appreciate your willingness to help us in evaluating the results of our labors.

From the point of view of HMC, the purpose of the summer study is to enable us to plan wisely for the educational purposes the College will serve. New colleges are rare, and there is much to be done in founding a college. It is, therefore, important to us to make the best use of our opportunity, but it is not easy to take the time from less important but more pressing matters.

The study this summer has been made possible by the Fund for the Advancement of Education. From the point of view of the Fund, as I understand it, the study is significant because Harvey Mudd College has an opportunity to experiment and attempt programs which may be of interest to many other colleges and universities.

We have therefore attempted in our summer study first to define the kind of engineer or scientist which we hope the Harvey Mudd graduate will become. Human variety being what it is, we do not expect all of our graduates to follow the same pattern, nor would we have them do so. But in thinking about the job the College has, we have found it particularly helpful to start by defining the type of graduate we hope to produce. We have then moved on to define the objectives of the College—what changes we hope are produced in our students by teaching and by their other experiences here. Once we were agreed on these general objectives, we explored what these objectives implied in terms of curriculum and hence in the staff and the faculties. The first conclusion is of course that the student must spend at least twelve years in college to learn the things he manifestly should know. Hence our last step has been to construct "trial" curricula which indeed could be encompassed in four years as feasibility tests of making appreciable progress toward these objectives within four years.

The formulation of any actual curriculum is of course the responsibility of the faculty at Harvey Mudd College. The purpose of the summer study has been to suggest ways in which the faculty may wish to develop the curriculum. Since the faculty of the College and the summer study group are of about the same size and have half their members in common, there has been no lack of communication.

There are some particular circumstances which apply to Harvey Mudd College, notably the fact that it is small, privately supported, and a

member of the Associated Colleges. Since it is small, the faculty can have at most a limited number of specialists in particular disciplines, but these faculty members will come to know each other well whatever their disciplines. Since the College is privately supported, it can use any standard of student selection that it chooses. As a member of the Claremont group, the College will be expected to adopt and maintain high standards of academic performance. The academic community in which Harvey Mudd students and faculty find themselves gives excellent support for scholarly enterprise, particularly in the areas of the humanities and the social sciences.

In establishing the purpose of the College at the time of its founding, the trustees planned for the developing of technical leadership. By its founding, therefore, the general goal of the College has been stated. The summer study has attempted to define this goal more specifically and to suggest ways of moving toward it.

Another circumstance we have borne in mind is that Harvey Mudd College is located in Southern California. We are surrounded by a complex and rapidly changing industry. California sends some 80% of its college students to publicly-supported institutions, and the University of California, the state colleges and the junior colleges offer wider educational opportunities in engineering than any other state can boast. Harvey Mudd College should therefore consider how it can best contribute to this supply and demand situation.

Fortunately we have had the benefit of ample help. The participants in this summer study have wrestled with similar curriculum planning at the University of Washington, Clarkson Institute of Technology, at Berkeley and at U.C.L.A., at M.I.T., at Chicago, and at Carnegie Tech. Members of our own faculty have, over the last year (with the support of the Fund for the Advancement of Education) visited relevant educational ventures at Yale, Brown, Swarthmore, Case, Carnegie Tech, R.P.I., Dartmouth, M.I.T., Reed, Antioch, and Columbia. In addition I would suppose that the participants in the summer study have collectively studied or taught in at least fifty domestic and foreign colleges. The American Society for Engineering Education maintains a continuing review of engineering teaching throughout the United States and regularly recommends ways in which engineering colleges can better meet our national needs. Some six of the participants in this summer study are, or have been, members of such ASEE panels, in subjects ranging from rate and transfer processes to the engineer's need to know Bach. Finally, we have had the help of the faculties of our sister colleges in Claremont who not only know what is immediately available on the Claremont scene but made it possible for us to call for advice on any specific discipline a liberal arts college can be expected to offer.

So much for what we have hoped to do through the summer study and how we have gone about it. For today's presentation we shall hear first from Professor White of Michigan, who will speak about trends, objectives and methods in engineering education. We will then hear from Dr. Trautman, now with the Ford Foundation, who will discuss specific curricula. Professor Campbell of Harvey Mudd College will speak on the feasibility of these curricula from the point of view of our particular situation. It will then be time for us to take a seventh inning stretch, or perhaps a fifth inning stretch. When we reconvene, Professor Jenkins of the University of Alabama, our philosopher, will speak of trends, objectives and methods in the study of the humanities and the social sciences as they bear on the education of an engineer or a scientist; Professor Chapman of the University of Washington will discuss specific curricula; and Professor Davenport of Harvey Mudd College will comment on these suggested programs seen from North Pitzer Hall in Claremont.

THE OBJECTIVES OF HARVEY MUDD COLLEGE

R. R. White

After President Platt's request that questions only as to the intelligibility of the speaker will be permitted, I warn you that I shall be thoroughly insulted if anyone asks me a question.

It is fitting that this preamble to a statement of objectives for Harvey Mudd College enquire briefly into the nature of the beast known as an engineering problem and the consequent requirements it imposes upon the human being who proposes to solve it.

You all know what sort of a fellow a scientist is. He has either a voluminous head of hair or none at all. He is pallid, frail, wears horn-rimmed glasses, and listens to nothing but Hindemith or advanced jazz. He is completely indifferent to girls—a cold sort of fish. (Comment by Trustee-Chemist Pitzer: "This is completely unintelligible!")

And of course you all know what an engineer is like: he is large, somewhat noisy, wears big hats and heavy boots and hangs gadgets from his belt. He listens to Hindemith because scientists do, and he is terrified by girls, exhibiting his panic either by outright flight, weight-lifting or mambo lessons.

I recite these stereotypes because they illustrate the tremendous change in the functions which engineers and scientists serve in our society. Not too many years ago the traditional engineering curriculum was a highly disciplined and regimented program, narrow in scope and concentrated upon rather specific skills.

During the past fifteen years we have witnessed a technological revolu-

tion staggering in its scope and incredible in its rapidity. In my short technical career I have witnessed the transformation of the petroleum industry from one which narrowly separated crude oil into somewhat coarse mixtures such as gasoline, kerosene and furnace oil, into a complex, highly technical operation based upon the isolation and conversion of pure hydrocarbons. I have seen the rise of nuclear power, ballistic missiles and missile systems, the aircraft industry—the list is endless.

Traditional patterns in engineering education have reacted to these changes largely with a greater emphasis on science but with a growing confusion as to what constitutes professional engineering and its practice. We have witnessed a prodigious rise in the quantity and quality of research and development in industry as compared to that in universities. Indeed, we now find many fields of a rather fundamental nature where the theoreticians and the leaders are in industry rather than in academic institutions.

One of the consequences of the technological revolution has been the emergence of the engineer with an increasing role as a responsible technical leader in problems having certain characteristics. These problems have indeterminable variables with the relationships between many of the variables either unknown or incompletely known. We recognize at once that there must be an infinite number of solutions to these problems, many of which may be good and many more of which may be bad. The concept of a "correct" solution then disappears. Another major characteristic is that we must optimize the solution with respect to men, money, time or materials, and must decide upon the proper one of these as a criterion for optimization. Finally, the problems are so complex and so large that the cost and time of the solution itself is an important consideration.

Men who undertake to work with such problems must have above all things a strong background in science which deals with the "certain" aspects. On the other hand an even more important ability is the capacity to deal with the uncertain and indeterminate aspects. All of this argues for a broad grasp of human knowledge based upon a strong science but incorporating above all else intellectual power which can be transferred readily from one area to another. To put it simply, we need a man with a capacity to specialize rapidly wherever he needs to rather than one committed to a specialty.

In the last analysis these requirements are neither new nor unusual. A medical doctor has the same problems with the number of variables, uncertainty and relationships and the necessity for optimization; so does a lawyer, a business executive or, in fact, any citizen who is an effective participant in his society.

We suggest that a sound education in engineering might approach the problem of the transferability of scientific and other knowledge through an emphasis upon what might be called "systems engineering." While other speakers will describe this in much more detail, in a sense systems engineering is the logical consequence of the philosophy of modeling which begins with the relatively simple models of pure science, progresses through the more complicated models of engineering science to the aggregations of components and sub-systems in the complicated arrays called "systems." It is an attempt to label the essence of the intellectual processes, characteristics of professional engineering.

To sum up then, the objectives of Harvey Mudd which are listed more formally in the document before you are: first, so stimulate the intellect of its students so that they will go on learning throughout their lives and, second to develop a broad, flexible intellectual power based upon science. At the same time we want them to lead full lives.

In conclusion I would like to say that Harvey Mudd has a unique opportunity to effect an important advance in engineering education. It is the most exciting educational challenge that I have ever met. The field is wide open, the job will take new men and methods, the location and time are most opportune for this promising new venture.

HOW WE BUILT THE CURRICULUM

D. L. Trautman

Devising a curriculum is itself an engineering problem, involving definition of purpose, boundary conditions, and the optimization of the many possible solutions against an acceptable payoff function. So we have been busy the past six weeks with "education engineering."

In our engineering curriculum proposal we have attempted a simple, straightforward approach through five main ingredients, instead of proliferating course titles. These five are:

> (1) and (2) mathematics and (pure) physical science—both relatively unchanging bases on which the engineer can build whatever new superstructure the future may require;
>
> (3) the humanistic-social base, of transcendent importance to the Harvey Mudd engineer-generalist who will be capable of accepting technical responsibility in a social context;
>
> (4) and (5) the two engineering bases, Engineering Science and Systems Engineering. The former seeks to organize basic principles around engineering situations, the latter to synthesize applicable knowledge and experience toward the design of an actual engineering system.

The Systems Engineering ingredient is a difficult one to name or identify, involving as it does professional orientation and approach, design and decision-making, immediate experience with problems and laboratory, and comprehensive attention to the unitary—or systems—aspect of a problem. For systems engineering draws not only on a variety of technical disciplines but also on various social disciplines, such as economics, law, and psychology. By its nature, then, this ingredient in the curriculum runs across the board of subject matter. Likewise Engineering Science is not restricted to specific subject matter but takes into account whatever fundamental knowledge is indicated for understanding the nature of given engineering systems. You will hear more about both Systems Engineering and Engineering Science from Mr. McCutchan and Mr. Meriam.

Now I want to give you some idea of the apologetics behind our proposed program and of the reasoning by which we arrived at the overall synthesis of these five ingredients. Our diagram shows the sizes and shapes of our five building blocks. We began by allotting equal time to each—represented by the vertical columns on our diagram—down through junior year. (The senior year will be charted later.)

	Math	Hum-Soc	Systems Eng'g.	Science	Eng'g. Sci.
Freshman					
Sophomore					
Junior					

With the boundaries thus tentatively established, we then considered how we might rearrange the blocks, with what effects and what advantages. The first suggestion was to so exchange time between Science and Engineering Science that the latter could build on the former; we therefore swapped a freshman course for a junior course. We kept sophomore Engineering Science, however, because it is important to provide some base for an intensive junior course.

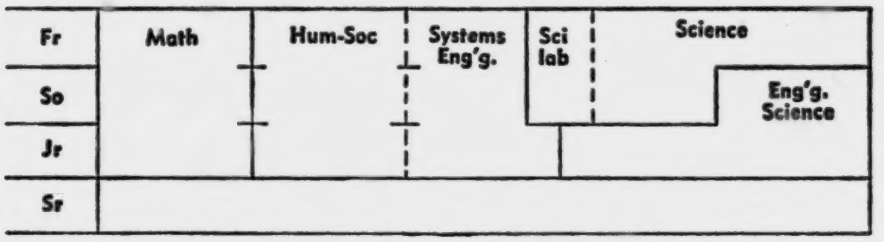
The major engineering field is often deferred to junior year, with the first two years devoted to "tool" subjects. However, Harvey Mudd wants to integrate knowledge through a design approach. It should therefore begin with Systems Engineering at the outset and carry through the entire four years. Similarly the Humanities and Social Science experience should be continuous.

Wherever possible there should be give and take. The Humanities column stands next to the Systems Engineering column in the diagram,

with breaks in between to indicate a close working relationship. Some time may be shifted from Systems Engineering to Science in order to allow concentration, especially in the science laboratory.

We want to allow a maximum of math and a consistent amount, so we leave this column unchanged.

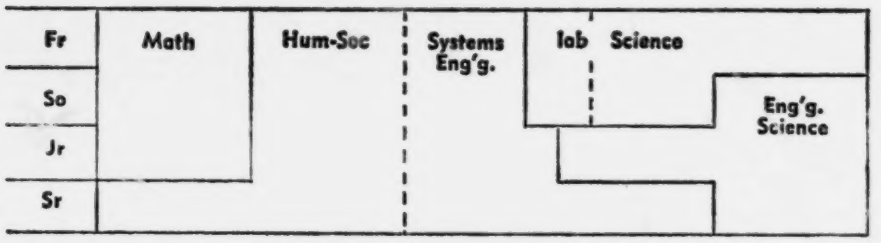
The diagram has now become:



We now come to the senior year, the student's climactic experience. Here he should be allowed considerable freedom and initiative to achieve his goals within the Harvey Mudd framework of Systems Engineering with a strong Humanities background. Thus we augment the Humanities allotment at this point, with perhaps an elective and a project. So also we increase the amount of Systems Engineering, with probably a technical design elective and a project. Moreover we recommend interplay between the Humanities and the technical elective.

The Engineering Science stem continues, with the range of elective choice broadened to include additional work in Science and Math, and in some cases perhaps the Humanities. The primary goal of this technical elective is penetration, so that the student can demonstrate his capacity to specialize.

The diagram has now assumed this shape:



We consider this distribution of time and emphasis consistent with the objectives Mr. White has set forth. Our program permits reasonable flexibility between blocks and within blocks. For example, the sixth semester of Math would probably cover concepts specifically related to Systems Engineering (discrete math, linear programming, computer math) and could just as well appear in the Systems Engineering block. A course in Engineering Analysis—which is certainly a necessity—could appear either in Systems Engineering or Engineering Science, though more probably the latter. The rationale of Systems Engineering could either be distributed throughout its block or be given as a separate course in senior year. Some interchange between Science and Engineering Science is obviously indicated. A unified junior lab for Engineering Science might be handled under Systems Engineering or as a continuation of the Science lab.

Furthermore, within the blocks, material can be organized in various ways. The Humanities portion of this afternoon's program will illustrate several possibilities which have received much thoughtful consideration this summer. The Harvey Mudd Science and Mathematics departments have also evolved representative programs (which have been distributed to you), recasting conventional materials and bringing them up to date to meet Harvey Mudd's demands. This leaves the two engineering blocks, and these I leave to my colleagues, Mr. Meriam and Mr. McCutchan, to describe more carefully and place in relation to the College's objectives.

THE ENGINEERING SCIENCE BLOCK

J. L. Meriam

It is my purpose to discuss the engineering science portion of the proposed curriculum. This 20% is the foundation on which a large part of the analysis of engineering is built. It includes the basic laws of the mechanics of solids both rigid and nonrigid, the mechanics of fluids both liquid and gaseous, the structure and properties of engineering materials, transfer and rate processes, theormodynamics, and electrical circuits and machines.

The Engineering-Science Subcommittee does not propose to specify the manner in which the engineering sciences should be presented.This is left up to the faculty to decide. We have, however, suggested various possible approaches to teaching them.

You may wonder why we do not go directly from the basic sciences to their application in engineering. This is a difficult question to answer for anyone who has not had intimate experience in engineering. It is best answered by pointing out the difference between the characteristic activities of scientist and engineer. Both use analytical tools for the descrip-

tion of a problem which requires a model. The scientist is interested in the simplest conceptual model he can devise to answer the question "why." The engineer on the other hand uses a model built as closely as possible to the real situation to answer the question "how to do it." Thus, it is the fundamental difference between the character of the conceptual models and their formulation which largely distinguish the scientist from the engineer. The training and experience needed for the construction of the engineer's models require more time and attention than is often supposed. The study of engineering science has as its goal the application of science to a real engineering situation; it is the means by which the wide gap between the basic sciences and actual engineering application is bridged.

Harvey Mudd College has an opportunity to help define the proper relationships between the basic sciences, the engineering sciences, and engineering design.

THE SYSTEMS ENGINEERING BLOCK

J. W. McCutchan

In the Systems Engineering—or professional—part of the curriculum we are interested in career orientation, tools of communication, elements of the design process, and indeed in a synthesis of all the various fields, with particular emphasis on the application of knowledge. This spectrum of experiences, involving as it does decision-making in the broadest sense, calls for the acquisition of particular attitudes, methods and approaches, and begins early in the curriculum.

There are two possible ways of approaching the curriculum: evolution and revolution. The former is exemplified by the recent gradual change of a drawing course to graphics, a surveying course to measurements, followed by the marriage of both. A revolutionary approach is represented by the organization of a course around an engineering function, such as the design of engineering systems, and the management of technical specialists by a (Harvey Mudd) technical generalist. Under this approach, course work can be conducted on a project basis, those projects being selected which require the tool skills of communication, whether descriptive geometry and drawing or the oral and written word.

Even at the freshman level, U.C.L.A. experience shows that introduction to design projects can be very successful. To give you some idea, such projects may be: community planning including social implications; communicating the features of a nuclear pump to the shop through drawings; displaying the operation of an aircraft landing gear in descriptive geometry; and the graphical solution of problems not readily amenable to analytical treatment.

In the middle years attention can be given to analogs and sub-systems drawn from various environments, and in the senior year to technical design in a given area, such as electrical, and also to a project. The latter two rest on the rationale of systems engineering, which delves into feasibility, reliability, producibility, cost, payoff function, and so on.

These examples are merely meant to suggest possibilities which the Harvey Mudd engineering faculty must examine as it draws up its specific program. One striking feature of the College is the unusual liaison between the Humanities and Systems Engineering. This will permit close and genuine cooperation all the way down the line, and will surely influence the College's entire orientation.

SOME TASKS FOR THE FACULTY

J. A. Campbell

If it is true that changing a curriculum is as hard as moving a graveyard, then we at Harvey Mudd are in a particularly favorable situation. Our graveyard is new, the graves are shallow, and none of the staff is closely related to most of the corpses.

One of the difficulties of asking advice is that you get it. The summer study has given us a good many plans, and it is interesting to compare them with our present situation. Each of us when we came had an established curriculum in mind, as did each of our visitors. Yet it has been interesting to notice the change in all of our positions as we have talked over the merits of the various proposals.

It seems clear to me that the great majority of the suggestions which have been put forward the last six weeks can fit our present schemes and can be applied immediately, at least in part. Any curriculum is a changing, usually growing (at times receding) thing. Our curriculum will continue to change, but it is important to take advantage of meritorious suggestions as quickly as possible. This, I think, we can and should do so that even our present students may profit.

All of the new proposals have in common with our present plans a fixed program for roughly the first two years. When one compares the current engineering suggestions with those we have had in mind, one sees that there is less "time" devoted to the sciences and the humanistic-social sciences, more "time" devoted to mathematics and considerably more to engineering and the engineering sciences. Yet it would be a mistake to view any of these curricular suggestions as fixed, or to consider the "time" allotment all-important. We all agree that broad variations are possible.

First of all, let me discuss the position of the science major in view

of the current suggestions. It is true that the summer curriculum study did not primarily concern itself with science majors. But, since roughly half of our students will probably major in either physics, mathematics or chemistry, it is important to consider their needs as well as those of the engineering majors. The greatest single change suggested has been the introduction—and notice that I do not say intrusion—of engineering into the first two years. This can be done in large part by a change of emphasis in the science courses themselves without losing the fundamental scientific approach. But it will also bring in some engineering or engineering science courses as such, especially in the laboratory. It will be a rare science major indeed who will not profit from such an introduction to engineering methodology.

What, then, of the general feasibility of these suggestions for the pre-engineering students and the decisions that remain for the faculty?

We have received considerable encouragement to venture and a great deal of help in establishing the bounds within which we should venture, but it would be a mistake to think of this summer study as suggesting primarily a distribution of "time" to various areas. The most important contribution is, rather, its distribution of emphasis. If we think only in terms of so much "time" for this field and that field, then we will have missed one of our main opportunities: to integrate the College in such a way that each of us is working toward a common objective with a similar emphasis rather than each insisting on the right to use his own "time" as he sees fit.

The summer study has insisted that courses should be recast rather than material merely reshuffled. Our job here is not primarily to decide which item will go where, but how over-all emphasis can lead to relationships of greatest profit to the individual student. For the progress of the individual student is our real goal.

The simplicity and homogeneity of the suggested curriculum can also be of great help in giving each student the same general background and frame of reference. However one consequence with which we will have to wrestle is the problem of electives. There is some question whether the best training for a student who is to be encouraged to make decisions is to give him so few electives in his college career.

How we take advantage of the study will depend primarily on the staff we attract. Unless each instructor is willing to reconsider his own field in the light of all others and the kind of students we have, we will have difficulty in capitalizing on our opportunities. Having achieved a staff of the required experience and venturesomeness, we can get on to the business of coordinating the courses so that we minimize overlap and maximize the building of one course upon another.

Let me close by mentioning some of the areas which seem to justify Harvey Mudd College in continuing along its present plans as modified and improved through the summer study. There is first of all a question of size. With this small number we will be able to change and coordinate work more readily and to keep track of each student more closely than would otherwise be the case. Our emphasis will be on undergraduate teaching, an emphasis not normally found in science or engineering schools. A homogeneous student body will allow us to plan our courses with less concern for a wide variety of student backgrounds or professional goals.

One of our principal advantages will be the strong emphasis on the humanities and the social sciences. The fuzziness of the boundaries separating these fields from the science and engineering fields should be emphasized. Not only will the humanities and social science work be directed to physical science and engineering students, but the science and engineering courses themselves will have a strong humanities-social science emphasis. An engineer will consider not only mechanical and electrical properties, but the physiological and social aspects of his problems. It might be wise to forget completely the classical titles for these areas in order to emphasize the integration in the curriculum.

The boundary between science, engineering science, and engineering will be similarly ill-defined. We will use a fundamental approach in all our courses, basing applications to particular problems firmly on the student's scientific background. Rather than preparing students for a special field of engineering, we will concentrate on producing persons with a wide acquaintance in the field—persons whose primary goals will be either graduate school or large industry in which they can then specialize.

Chiefly we will be unique in two areas: (1) We will have close coordination between courses. We will consider the humanities, social science, science, engineering fields not as separate means of achieving a goal, but as each contributing its own accent, while always bearing in mind the merits of the other fields in the over-all education of the student. (2) We hope to attain and maintain a spirit of venturesomeness for a long period of time. We shall hope to keep both the goals, and the methods of attaining them, open as long as possible. If we can attain this degree of venturesomeness and the enthusiasm of both students and faculty, the efforts should yield good ideas, good execution, and good graduates.

QUESTIONS AND ANSWERS

Mr. Pitzer: What's the purpose of using the word "systems?" I'm distrustful of jargon that is popular today but may be outmoded to-

morrow. Does Harvey Mudd College want to identify its engineering program as "systems engineering?"

Mr. Wig: Yes, what degree would be offered under this plan?

Mr. Platt: We have talked of offering a degree in engineering science. In considering the systems approach we have been concerned with crossing the lines of demarcation between academic departments. Any mechanism that permits crossing the usual boundaries will be helpful.

Mr. Moore: Are you looking for a particular kind of student for this program? Do you propose to turn out a generalist rather than a specialist? And is there some means of selecting potential generalists?

Mr. Platt: We feel that training generalists is the most fruitful purpose for Harvey Mudd College. We try to select and tend to attract students who are more likely to develop into generalists.

Mr. Walker: Yes, this is our aim, although I know of no selecting device to single out potential generalists at high school age.

Mr. Davenport: We hope to produce students with enough problem-solving experience in all fields to adapt to specialized situations.

Mr. Meriam: The term "systems" connotes the trend away from old-fashioned specialization toward integration of elements drawn from all directions.

Mr. Johnson: What do you expect your students to do after graduation?

Mr. Platt: Our best guess, based on the present class—and this is all we have to go by—is that a majority of our students will go on to graduate study. There they would be ahead of most other students in basic sciences but behind most in engineering work. This probably means that they will be behind during the first year but ahead thereafter.

OBJECTIVES OF THE HUMANITIES-SOCIAL SCIENCE PROGRAM

IREDELL JENKINS

Mr. Platt has stated that in no area of education is the pressure of time and conflicting demands so severe as in engineering. I would extend this a bit further, and say that in no region of this area is the pressure so severe as in that which deals with the non-technical phase of such education, including philosophy, the humanities, and the social sciences. It is my pleasant, if difficult, task this afternoon to explain to you the importance that we attach to this part of the proposed Harvey Mudd program. A good deal more of the students' time and effort is here to

be devoted to this phase of his education than is usual. It is not as much as we would have liked; but it is still more than we might have expected. So it is incumbent upon us to justify this allotment, and to explain the uses to which it shall be put. This requires a consideration of the ends that such a program seeks, the functions it performs, the values it promotes. Most briefly and realistically, it is a matter of the impact of a program in the humanities and social sciences upon the students who experience it.

Such a program serves three chief aims. Two of these ar idely recognized and implemented, and I will discuss them but briefl

a. It is instrumental to the professional training of engineers and scientists strictly as such. Courses in report-writing, communication, logic and scientific method, economics, psychology, management, and many others have a direct utilitarian value.

b. It contributes to the development of students as whole men, furthering the realization of their general human attributes as well as their special vocational capacities. Courses in philosophy, literature, the arts, history, and others open new vistas of experience and so make possible a richer participation in life. They aid the student to cultivate life's opportunities and to enjoy its occasions.

These are real and legitimate aims. We accept them, and intend that our program shall promote them. But there is also another and more significant aim that we have in mind for the humanities and the social sciences in the Harvey Mudd plan.

This further purpose can be introduced in this way. We take very seriously and literally the oft-repeated statement that men who are trained as scientists and engineers are moving more and more into positions of general leadership, where they exercise great power and bear corresponding responsibilities. Such men are exerting a continually greater influence in economic, industrial and even political affairs; they are playing an ever larger part in making the decisions that define social purposes and policies. We accept this as both an accurate statement of present trends and a sound prediction of the future. We envisage the chief end of this program to be that of training scientists and engineers who will be adequate to this new role that they must fill.

Accepting this interpretation of the actual course of events, three questions arise:

1. How and why has this come about?
2. What does it mean for engineers and scientists?
3. What does it mean for engineering and scientific education?

We must briefly consider each of these questions.

This belief does not presuppose any political coup d'etat, any new "managerial revolution," or even any radical changes in the structure of the economy or of government. It simply means that individual scientists and engineers, strictly as individuals, are coming more and more to occupy positions that entail the direction and leadership of large-scale human efforts.

The reason for this movement of events is simple. Scientists and engineers are the masters of the techniques of control through which man dominates the physical environment—and, to an ever increasing extent, even the human and social environment. As this power of control increases, its effects upon the lives of men grow more pervasive: until now there is hardly any area of the world—whether physical or human—that technology cannot reach and modify. This in turn means that scientists and engineers are coming to confront possibilities and problems that are quite unique in their experience. Hitherto the question facing them has been largely that of what they *could* do: now it is much more a matter of what they *should* do. With this vast extension of technical potential, mankind must decide to what uses it is to be put and what values it is to serve. Questions which were previously the subject of mere Utopian speculation now become issues of immediate practical concern: purposes must be enunciated, and policies formulated, in areas where man could hitherto indulge in pleasant but idle dreams. What were easy wishes now become hard decisions.

Because of their mastery of the techniques of control, scientists and engineers are indispensable in assuring that policies will be efficiently executed and purposes effectively achieved. Under these conditions, it is inevitable that such men will be more and more called upon to make decisions about these purposes and policies themselves. Until quite recently, scientists and engineers had their problems, goals, and values set for them by others: they merely possessed special skills that they put at the disposal of those who needed and wanted them, taking little part in defining the uses that were to be made of these skills. In short, they were both specialists and subordinates. As such, it was only their technical education that was important to anyone except themselves. But now scientists and engineers occupy many of the positions of dominance in wide-spread areas of society: in government agencies, the armed forces, industry, finance, education, etc. Such men obviously play a large part in defining domestic and foreign policy, in settling the distribution of our natural resources, and in deciding toward which of various goals our energies will be directed. The mastery of means soon forces men to face the issue of ends.

As a result of this process, many scientists and engineers are now in positions where their influence is pervasive and dominant. This can be put quite brutally by saying that their mastery of physical power is being transmuted into the mastery of social power. It can be put more gently by saying that they are becoming "instrumental in the creation of a new society and a new economic order, as well as a new physical environment" and that they must consequently "accept an increasingly responsible role" (ASEE Report on General Education in Engineering). Either set of terms means that scientists and engineers are facing the challenge of general human leadership. It makes little difference that this often happens without any intention, or even any real awareness, on their part—or, in fact, against their wishes. Even if these men refuse power and responsibility, they still must decide to whom to abdicate them. That is, they must decide what quality of leadership and direction they will accept. Unused power creates a vacuum, and even if technically trained men refuse to rush in here, they must make up their minds whether to follow fools or angels.

Under these conditions, it obviously becomes a matter of great import that scientists and engineers be equipped to administer with intelligence the power and responsibility that are being forced upon them. This requires that their technical education be strongly reinforced with the philosophical, humanistic, and social disciplines. These men can no longer confine their attention to the concepts of feasibility and efficiency. They have now got to be concerned with ends, with values, and with the total contents and conditions of human well-being. To deal with these effectively, they must have an appreciation of man's past achievements, a sense of the possibilities that lie open before man, a realization of human limitations and a sympathy for human differences, the ability to balance alternative values, and the informed courage to make the sacrifices and compromises that life and the world demand.

We come now to the final and crucial question. How can this be done? Through what sequence of what courses is all of this to be achieved? Fortunately, I can leave the detailed discussion of this problem to some of my colleagues. So I shall merely sketch the framework of the answer. If the program is to have the effect we wish, it must accomplish three things. I shall identify these phases as Dogma, Theory, and Practice. Before describing these, I must insist that they are not separate and independent—much less rival—undertakings. Rather, they are intimately connected, and any work in one of them inevitably involves the others, at least incidentally. But they are different tasks, and each must receive its due stress.

Dogma: The task here is to familiarize the student with the cultural processes and achievements of the past. This transmission of the tradi-

tion combats the provincialism that is otherwise so prevalent; without such training, men isolate themselves in space and time, losing touch alike with their contemporaries and their forbears. The effort here must be directed toward imbuing the student with a sense of time, of the continuity of effort through time, of the possibilities that this effort has partially realized, and of the responsibilities that we have inherited from the past. This must not be allowed to degenerate into a worship of the past simply for its own sake: though such worship is an indispensable ingredient in any intelligent respect for the future. But the primary end of such study is to enable each generation to stand on the shoulders of its predecessors. This is probably the most familiar and widely acknowledged task of programs in the humanities and social sciences. Here it need only be pointed out that the technical phase of the curriculum need not concern itself to any extent with this task. It becomes virtually the sole responsibility of the "liberal" aspect of education, and burdens this most heavily.

Theory: The task here is to equip the student with conceptual systems—theories—in terms of which to understand human and social phenomena. This has its technological analogue in the work in the basic and engineering sciences. These afford the student an intellectual mastery of the physical environment. Similarly, it is a task of the non-technical program to afford him an intellectual mastery of the human and social environment. This is given by such basic disciplines as ontology, epistemology, axiology; and by such more specialized sciences as psychology, economics, sociology, political science, and others.

Practice: The task here is to equip the student to participate actively and intelligently in his culture. This is the most difficult part of the program to describe—and, more important, to execute. It is the analogue of work in the scientific and engineering laboratories, where the student is trained to acquire knowledge of the physical world by inquiry, and to apply this knowledge by technological methods. Similarly, the student must be trained in analogous skills that bear upon his wider human and cultural surroundings. His aesthetic sense must be cultivated. He must be helped to apprehend with sensitivity and discrimination what his contemporaries are saying and doing. He must learn to express himself and to communicate with his fellows. This requires training in such varied areas as these: reading; seeing; listening; analysis of written material; writing; speaking; logic; scientific methods; rhetoric; graphic art.

It is here that the entire program in the humanities and the social sciences comes to bear at a point, and merges in a common ambit with

the technical program. For the purpose of all these disciplines is to train the student to take an active part in the continuing process of which tradition and theory are merely the present embodiment. It is to enable him to participate meaningfully in the culture he has inherited, and to contribute creatively to the culture that it is our common task to bring into being.

And now Mr. Chapman has the pleasant and easy task of telling you just how we propose to accomplish this.

PROPOSALS FOR THE HUMANITIES AND SOCIAL SCIENCES

S. W. Chapman

After hearing Mr. Jenkins on the objectives of the humanities and social sciences in the Harvey Mudd curriculum, you will immediately understand why I am going to discuss four proposals rather than just one. Obviously, we were able to work out a program to match the objectives in just one week, and spent the remaining five weeks dreaming up other proposals!

This easy explanation of our fourfold curriculum comes as something of a relief. I feared for awhile that the contrast between the single curriculum for engineering and our four might be taken as evidence that the co-chairmen of our subcommittee couldn't keep their colleagues in line or that our group was composed of fuzzy-headed, starry-eyed, stiff-necked individuals who refused to get together. Actually we planned, almost from the beginning, to suggest more than one program.

In presenting the four proposals for the humanities and social sciences, I shall consider: (1) the reasons for offering four proposals; (2) the objectives common to all four; and (3) the differences in approach represented by the four.

We offered more than one proposal because we were aware of the many different curricula already existing in engineering colleges around the country, and knew that there was no single best way of achieving our objectives. We recognized also that the Harvey Mudd faculty would have to plan its own eventual program; we could not do it for them. Therefore we felt that we might best contribute several proposals, each of them suggestive of possibilities that deserved consideration. I might add that each of the programs you find in our preliminary report has been revised at least once, and that each would undergo further revisions, particularly in view of the reduced time allotted to the humanities and social sciences in the curriculum just described by the engineering group.

Now for my second point, namely the common objectives which can be found in all four proposals. We early agreed upon objectives. Fortun-

ately we already had those formulated in the reports of two committees of the American Society for Engineering Education. These, commonly called the Hammond Committee objectives, with some additions and changes, you will find in the statement of aims on pages 1 and 2 of our preliminary report. Let me now give some examples as evidence of the fact that each of the four proposals was drawn up with the objectives clearly in mind.

The first objective is to help the student "to understand our social organization and the influence of technology on its development." Material aimed at this objective can be found in the curricula and courses as follows:

Chapman proposal	Introduction to Humanities and Social Sciences Economic Analysis Functions of Government The Individual and Modern Culture
Jenkins proposal	Intellectual and Institutional History Contemporary Cultures Contemporary American Culture Theory of Law and State Economic Theory and Analysis
Phelps proposal	Some in the distributional requirements Much in areas of concentration such as economics, political science, and history
Rieff proposal	A basic part of all the work of the first three years, and of one of the suggested areas of concentration

The second objective is to help the student "to analyze intelligently problems involving social and economic elements." This goal would be sought explicitly in all of the courses mentioned above, and implicitly in many others.

The third objective is to help the student "to express thoughts logically and lucidly." A quick glance at the four proposals seems to indicate that this objective was entirely forgotten in three of them. This impression is deceptive. Actually we are agreed that practice in good writing is a function of every course and a duty of every instructor.

The fourth objective, to help the student "to understand the nature and significance of literature and the fine arts," appears in the following places in the proposed curricula:

Chapman	Literature, Art and Music, as well as Introduction to the Humanities and Social Sciences
Jenkins	Art and Literature, Intellectual and Institutional History, Contemporary Cultures
Phelps	Distributional requirements and humanities area of concentration
Rieff	Social Sciences — Humanities I and II, Humanities I, Humanities area of concentration

I could go on to give more detail, but I hope that these examples provide sufficient evidence that all four of our proposals, different though they may be, are actually working toward the same objectives.

Let me go on then to my third point, the differences in approach to the objectives. Basically these are two: (1) in the degree to which practices and courses already in common use in liberal arts colleges could be used also at Harvey Mudd; and (2) in the proportion of the curriculum which should be in core courses and in elective areas of concentration. Again let me give examples. Mr. Phelps' program is built entirely upon traditional courses and the common liberal arts principle of requiring both distribution over several fields and concentration in some one field. This proposal places more stress on an elective area of concentration than does any other.

The other three proposals give greater emphasis to a core program, and one in which new courses would have to be developed to include materials taken from traditionally discrete disciplines. Mr. Rieff's plan requires a core program for three years; all of it would have to be newly developed. Mr. Jenkins and Chapman propose more separate courses, but most of these would have to be newly developed, at least in part, because so many of them would require new approaches and would cut across different fields. In each the intent would be not to concentrate on memorization of facts but rather to emphasize basic concepts and theories. Incidentally, each of these three proposals makes provision for an elective area of concentration, though less than that suggested by Mr. Phelps.

One final general comment. Although this is not evident in the wording of our proposals, there was strong sentiment in the committee that one of the great opportunities at Harvey Mudd is to bring the technical and humanities stems together. Such work might start early in the curriculum and expand in later years, particularly in a senior project. Most engineering schools with humanities programs hope that their graduates will approach problems with human and social implications in mind. Harvey Mudd is in a position to plan, from the beginning,

to give the student such experiences before he leaves college. If it can succeed in doing so, it will indeed make a significant contribution to engineering education.

FACULTY COMMENT ON THE HUMANITIES AND SOCIAL SCIENCE PROPOSALS

W. H. Davenport

When Mr. Jenkins turned over the speaking duties a few minutes ago to Mr. Chapman, he was heard to invoke the Deity to come to the latter's assistance, whereupon Mr. Chapman was heard to remark that this was the first time he had heard the Deity invoked in the course of the whole conference. This is a bit reminiscent of a story that has been making the local rounds lately: a certain individual had occasion to visit a church of the more modern experimental variety and was talking about his experience with a friend. In answer to the friend's query as to the workings of the new faith, our original character replied that he found it very interesting but that the only time he had heard the Deity mentioned was when the janitor fell downstairs. Lest anyone present fear that the four programs submitted in the humanities and social studies have side-tracked religion, I hastily add that a re-reading of those programs will show that the spiritual values of mankind are not slighted historically or theoretically. Furthermore if any of you feel that the fact that the engineers have come up with one plan and the humanists with four is merely another indication that the engineers are practical and know what they are doing, and the humanists are dreamers who cannot make up their minds, I should like to say firmly that any one of the four plans will work: we merely have to pick one horse from the stable and ride away.

My assignment this afternoon is to show points of resemblance among the four plans suggested by the non-technical group. Speaking of agreement, of opinion, I might say parenthetically, that there is probably one thing that all of us here this afternoon agree on at the moment—that in a few minutes a walk in the fresh air, followed by a social period before dinner, would be most welcome. To resume, if you will allow me some freedom with categories, I can detect three areas in which there is substantial agreement among the four programs mentioned. The first may be called the Ideal. You will note that all of the programs stress the importance of the past in religion, society, and culture. They likewise show considerable concern for the s nt, engineer, scientist, or liberal arts major for that matter, who must face the strains and stress of the present, of living in what has sometimes been called the Benzedrine Era.

Something of the tempo and hollowness of modern living can best be seen by some rapid illustration, itself a concession to the modern demands for speed. To lump together several vaudeville-type gags, I might remind you that ours is the only civilization to produce a magazine with a title like *Quick*. Of this publication, Clifton Fadiman once said we should now produce a *Quicker* and then a *Quickest* and then blow our brains out. Again, not so long ago, in a store window in Alhambra I saw a sign labeled "Fiction, 6 cents a pound." Surely this is the very nadir of taste. Or again, we are said to be the only civilization in which, if you call upon someone at night and find all of his lights out, you know he is home. Or to put it another way, ours is the only civilization in which a magazine feels that it has to publish reading time at the head of its articles. In effect this means, How long can you sit still? And, finally, here is an experience one of my staff had not too long ago at a large metropolitan institution not too far from here. The young instructor, in the middle of an English class, came on a reference to the Battle of Hastings. He thought it was a good time to bring in a little history and casually asked if anyone could tell him the date of this battle, one of the great turning points in history. No one could give him the answer. In disgust he asked the phone number of the Smiling Irishman (a used car dealer who was bombarding the airwaves with his slogans at that time). Back came the chorus: "Hudson 2-7272." In great disgust, my young friend did what is very effective about once a year in any class—he dropped his book on the table and walked from the room. At the next session, the class—much cowed and much impressed—nevertheless produced a spokesman who had the final word. He said, "Gee, doc, if they had only taught us history in as colorful a manner as the advertisers use in their blurbs, maybe we would have remembered the date. Now if they had told us it was Hastings 1066 . . ." We have been talking throughout the foregoing examples of matters that relate to taste and to values. All four programs stress these matters very emphatically.

The engineer and scientist is treated in all of the programs as a whole man, then as a generalist with theoretical possibilities for adaptation, and finally, in some cases, as a specialist. A few weeks ago, in the course of the conference, Mr. Rieff defined for us the word "barbarian" as referring to a man who has nothing to remember. It is our job, as these four programs show clearly, in the humanities and social studies, to turn the engineer and scientist to those pursuits which may be said to be civilizing in the best sense of the word. All of us wish to show the student that there are other forms of truth than the quantitative, that fact is fine but imagination is also important, that job responsibility is good but so is moral responsibility, etc.

The second area of common ideas may be called the pedagogical. All four plans agree on the need for some electives, a substantial amount of

required subjects, some concentration, however limited, in minor areas instead of random smorgasbord or *hors d'oeuvres* approach, constant practice in writing and communication generally (this is a national problem), and emphasis on fact, practice, and theory, not just any *one*.

The third area, which we may call the futuristic, shows again agreement on objectives, as indicated by Mr. Chapman. You will note common emphasis on history, problem-solving, clear expression, aesthetics, personal code, an inquiring as well as informed mind, and finally the enjoyment of life, again in the best sense of the word. It is likewise agreed that the Harvey Mudd faculty will be the ones who will ultimately decide on plans or modifications, and here local conditions such as personnel and facilities will prevail. We are likewise unanimous in expecting follow-up study, changes under fire, periodic review, and in-service staff training. It well may be that next summer will find English teachers re-reading Plato and reading Jung for the first time, while experts in Renaissance art may have to discover something about the sonnet. This is a very good thing for faculty and students alike.

Finally, as we draw to a close of a long session, we would all agree, I am sure, Claremonters and visitors alike, that HMC has a unique opportunity to be at the head of the parade in engineering science. The present assemblage of local and visiting faculty, trustees, administrators, men of industry, representatives of foundations, and just plain friends who have dropped everything to sit in with us today is a remarkable indication of confidence in, and hope for, the Harvey Mudd experiment.

EVENING SESSION

Mr. Platt: You have heard the conclusions of our two committees and examined the programs they propose. I should now like to call on our visitors and trustees for comments and questions. We might begin with Dean Pitzer who is not only a member of the board's curriculum committee but an old hand in the education business.

Mr. Pitzer: I can see the advantage of giving the student engineering early in his education but question the amount allotted in the first two years and indeed in the whole undergraduate program for what you hope to achieve. I also question the emphasis on broad engineering problems at a stage when the student is not yet prepared to cope with them; isn't this rather the province of the graduate school?

Mr. Wig: There is considerable advantage in giving the student some idea of the problems he must later meet.

Mr. Meriam: During the first two years the program only provides for two hours per semester of professional engineering, a very limited

allowance. The purpose here is to introduce the realities of engineering and to orient the students in the field. The engineering program broadens in the third and fourth years, but even at that, the core of the program, (that is, the laboratory work) comes essentially in junior year and the first half of senior year.

Mr. Walker: Why spend the lion's share of your time on engineering as against 25% in humanities and social sciences?

Mr. Platt: To give perspective on this question, I should point out that an engineering curriculum that allows 25% to the humanities and social sciences is close to the world's record.

Mr. Walker: This sounds like comparative morality to me.

Mr. Platt: In any case, 25% is not a final figure. The engineers have proposed it, but we have also been toying with a 35% allotment to the humanities and social sciences. The actual percentage remains to be settled in practice.

Mr. Cooke: Doesn't professional engineering entail work in the humanities and social sciences as well as the sciences and engineering?

Mr. White: This program is very strong both in the basic sciences and in the humanities and social sciences. But if you are to train an engineer you must go beyond scientific exactitude and humanistic or social breadth: decision-making is the heart of the matter for an engineer. It's important to start this decision-making process early and then to build on the student's growing scientific and mathematical knowledge.

Mr. McCutchan: Moreover the student should be exposed early to quite specific problems.

Mr. Wig: In teaching the social sciences, let's say economics for example, would you take up problems affecting or involving engineering?

Mr. Phelps: Personally I would prefer to teach economics as a liberal discipline in its own right, beginning with theory before taking up particular problems.

Mr. Rae: We should beware the danger of superficiality in the humanities, which is bound to be much greater than in the sciences or engineering because of the student's orientation and the limited share in the curriculum of the humanities.

I should like to elaborate on Mr. Wig's earlier question: What will happen to the HMC graduate if he decides to go on to graduate work in a field other than science or engineering? MIT offers a program with a 50-50 scientific-humanistic split for students who propose later to use science in non-scientific careers. Now it strikes me that HMC could aim

at a point halfway between this 50% and the usual 20%-minus humanities in the average MIT undergraduate program. Moreover HMC as one of the Associated Colleges has a rare chance to tailormake programs for the individual student.

Mr. Wig: Would enough philosophy and religion be taught the HMC student to give him some stability and sense of values?

Mr. Davenport: The question might rather be: How much would he need to achieve a personal philosophy and code? Every program we have proposed includes some religion and philosophy.

Mr. Phelps: I have been doing research on the humanities and social science courses offered at three colleges taken at random, Lawrence, Oberlin and Pomona. I find that one of them—Oberlin—offers some 485 separate courses in 19 different disciplines in the humanities and social sciences alone. Now HMC is limited to 11 semester courses in this area. What disciplines are you going to choose? Will you give your student a sampling of 11 different disciplines, leaving him with a smattering of each and no sense of a single one? Considering the tremendous variety of possibilities, we have drawn up programs in the humanities and social sciences that overlap and coincide to a remarkable degree.

Mr. Rae: The question is not so much how many courses you offer but what you cover in your courses and the kind of teachers you have. Surprisingly enough, at MIT we feel constant pressure from students for more offerings in religion and philosophy; MIT has been trying to develop resources in this area both in the curriculum and in extracurricular opportunities.

Mr. Chapman: I don't believe humanistic-social studies will necessarily save the engineer or for that matter create the well-rounded individual in a liberal arts college. But the kind of program we've been discussing will surely give the basic human values we want to transmit.

Miss Paschal: It is extremely difficult to determine how any college gives its students a sense of values. HMC as a new college is in a position to decide on the values first and then to plan its courses so that they will count. It might be advisable for this purpose to abandon the traditional disciplines and create a totally new curriculum, one that might well prove far more effective than most liberal arts programs.

Mr. Rieff: I must confess that I cringe a bit whenever I hear the word "values" bandied about. We all agree that one of our important tasks is to transmit our cultural tradition. I believe we should not stop there but pass on also the attacks on our traditions and values. The approach to culture or values should be not merely polite but inquisitive.

Mr. Cooke: I should like to ask Orme Phelps how many courses an average undergraduate would take out of the total of 485. About 40? Then what is the usual balance between the sciences and the humanities in a science major's program?

Mr. Phelps: As I have pointed out previously, the distribution of non-major subjects at HMC comes very close to that at Pomona. I'm impressed by the fact that you can manage to give the student all this and engineering too.

Mr. Coberly: We have so far talked mostly about curriculum. Have you considered whether there is any teaching method which might expedite the learning process?

Mr. Pitzer: Certainly HMC has the advantage of beginning without any of the constraints that bind and limit existing institutions.

Mr. Johnson: HMC is not entirely free of constraints. For example, you are bound by the existing school and college system.

Mr. Platt: We have given this question a great deal of thought. At the lower end we considered early admission, reviewing for instance the University of Chicago plan of accepting 11th graders. We came to the conclusion that this plan, while educationally desirable, does not prove socially or financially practicable at Harvey Mudd. At the other end we found ourselves faced with another constraint, the task of preparing students to enter graduate school.

Now the best way to make the most of your time is to cut out duplication. We have explored this question thoroughly and found areas where real economies can be made by careful coordination of courses. Jenks has suggested another method of saving time: by determining elements of theory around which the facts can be most profitably organized.

Mr. Wig: I should like further comment on the program from the industrial executives present.

Mr. Johnson: How many of your students do you expect will be engineers and how many scientists?

Mr. Campbell: We have of course only one class of 48 students to go by. Of these 50% have indicated a preference for engineering, 20% each for physics and chemistry, 10% for math. Obviously it would be rash to predict anything at this stage, but I believe our students are more likely than most to follow through. They are a highly selected lot with a marked aptitude for the sciences, and they have already given a good deal of thought to the vocational question before coming here.

Mr. Platt: Besides, during their first two years they will all have ample opportunity to consider the four choices available, since they will all take the same broad program before making the choice.

Mr. Johnson: I note that no provision has been made for language or biological science. Are these subjects taught in other colleges at Claremont?

Mr. Platt: Yes, there are excellent courses in both these areas at Pomona, Scripps and CMC, and our students will be able to take them as electives. This raises another question we have puzzled and debated at length, both during the summer study and before in faculty seminar. Our present thinking is that our science and math majors will probably have more elective time than our engineers and will probably want to elect language if they are going on to graduate work.

Mr. Meriam: We should point out that there are many places in the program where students could choose electives or vary the emphasis we have indicated. For instance, math or physics or even humanities could be substituted for the engineering science electives in senior year. There is more freedom and flexibility, more possibility for exchange between disciplines than might at first glance appear.

Mr. White: There are many roads to intellectual salvation, and the intellectual process is always the same, regardless of the frame of reference of a given field. This I discovered by going on to law school after a Ph.D. in chemical engineering. Transfer of knowledge makes the difference between education and training, and knowledge or learning becomes valuable when it can be transferred from one realm to another. We cannot in any case hope to cover even a single field entirely, let alone the entire range of knowledge; so merely covering a certain amount of subject matter is not the be-all and end-all in education. What we are talking about here is a kind of engineering education that amounts in effect to a liberal education.

Mr. Johnson: I want to quote one observation Mr. Moore made before leaving and would no doubt have made to the faculty if he had stayed. The HMC faculty will have to face the challenge of matching the motivation of students who might well be interested in going to the moon or building a nuclear reactor but might not be interested in bettering mankind. There is a danger here that the students will miss some of the essentials that the educators feel they should have.

Mr. Rae: This is a challenge faced by the faculty at every technical institution; it is not peculiar to Harvey Mudd. Certainly HMC with its emphasis on undergraduate education has a chance, not to be found in other engineering schools, to keep the students aware of human and social values.

Mr. Chapman: The danger is much smaller than it was formerly. Over the quarter of a century that I have been teaching I have watched a noticeable change taking place in the mentality of scientists and engineers. There is an increasing awareness among them, especially in the last dozen years, of human and social questions, and what's more, they are increasingly drawn to the humanities and social sciences as a relief from engineering.

Mr. Johnson: I certainly think it desirable that the non-technical studies be regarded as ends in themselves, not merely as tools or subordinate disciplines.

Mr. Coberly: On behalf of the board members here and of those who are absent I want to thank President Platt and all of you here for this extremely stimulating discussion. I can see that the summer study has been an important milestone in the College's history, and for my own part, I have found it a rewarding and enlightening experience to be here today. Thank you.

THE ENGINEERING PROGRAM AT HARVEY MUDD COLLEGE

July 29, 1958
(revised August 8, 1958)

This report on the discussions, conclusions and problems of the engineering-science committee of the Harvey Mudd College Summer Curriculum Study *is not to be read as a final synthesis* but rather an attempt to work toward that eventual synthesis. The committee realizes that the faculty itself must develop the final program in actual practice.

OBJECTIVES

Engineers engage in the science and art of the possible to satisfy man's desires through creative design of acceptable systems and their components involving matter, energy, information, man and his environment. Their activity is both pragmatic and systematic because of man's basic urge and oftimes necessity to press toward increasing mastery of his physical environment. Pragmatic activity deals with the practical and effective use of unformulated and often incomplete knowledge, systematic activity with the use of facts and principles leading to a system of prediction and control. The "creative design of acceptable systems" identifies a non-routine synthesis of knowledge and experience to produce an entity (system) with a given solution meeting relevant criteria. This involves an optimization of design with respect, e.g., to performance, producibility, reliability, cost, and indeed also with respect to the effort of executing the design itself.

A serious question of technical and educational orientation for Harvey Mudd arises by virtue of its smallness and its concentration on undergraduate teaching. Can the College realistically provide the academic preparation for the engineering activity just described? Departments of pure science already exist at Harvey Mudd; the next step toward engineering is applied science—the practical as viewed by scientists; then engineering science, or the theoretical as viewed by practitioners; and finally engineering itself typified by the design process. A serious suggestion was proffered that Harvey Mudd concentrate on Science and Applied Science as the best compromise among possible curricular objectives, staff recruitment, facilities, and other resources. An Engineering Science orientation runs the risk of becoming Applied Science in disguise and could involve a presumptuous use of the modifier "engineering"; and a program with one or several of the conventional departments of engineering is clearly not feasible or desirable.

However, the engineering-science committee was reconciled by combining two facets of a national movement in engineering education. It proposes:

1. strong scientific orientation
2. pronounced attention to engineering methodology including systems design.

Thus the announced curriculum for Harvey Mudd would be to educate the future Systems Engineer.

A Systems Engineer has been described as a man who, when assigned to a project, is capable of coordinating and preparing or carrying out three things:

First, an optimum scheme (system survey) showing the interrelation of all factors that will affect the project and sway future action.

Second, an optimum set of organized ideas (the plan of procedure) pertaining to carrying out the project.

Third, an optimum physical realization (the product) of the devices necessary to terminate the project.

The process that involves these three steps is called the systems design process. Specifically, study of engineering at Harvey Mudd College should help the student

1. to prepare for graduate school or industrial organizations with initial training programs;
2. to assume responsibility by virtue of his personal motive and operational understanding of technology, self and society, and their interrelations;
3. to understand the nature of the physical universe to a degree sufficient for prediction and control, and continued learning;
4. by virtue of this capacity for continued learning to penetrate unfamiliar fields rapidly and with confidence and extract the essentials pertinent to his purpose;
5. to master an effective approach for the application of this knowledge in any area stemming from the physical sciences;
6. to formulate a problem involving economic and social as well as technical constraints;
7. to determine the bases for resolving a problem situation often involving uncertainty and various levels of values and reach a timely decision;
8. to find lasting interest and pleasure in these pursuits.

METHODS OF ACHIEVING OBJECTIVES

The engineering-science committee recommends that the implementation of these objectives for Harvey Mudd College be guided by the following:

1. All engineering staff members be in one administrative department. Problems in establishing engineering on this campus are more severe than those in science; hence every effort should be made to begin immediately, and without compromising the goals too seriously.

2. The degree be termed Engineering Science of Systems (or Science of Engineering Systems). Engineering Science is the degree closest to science recognized for accreditation by the Engineers' Counsel for Professional Development. The term "systems" in the title should induce the faculty to lean heavily toward "Systems Engineering" — in which area Harvey Mudd is much more likely to make a unique contribution to engineering education.

3. The Humanities-Social Science portion of the curriculum be 32 semester hours of a total of 128. While this committee is not charged with the development of the non-technical program, it is somewhat sensitive to the amount of time so used. The proposed amount appears adequate to achievement of the above objectives.

4. The first two years of engineering be common with science and mathematics. Specific course topics in the proposed program have been reviewed by science and mathematics faculty, and all concerned are in accord.

5. The entire program involve integration of knowledge around the leading concepts of the essential characteristics of engineering activity. This may call for the recasting of traditional courses and a high degree of liaison among all faculty members —whether in science, mathematics, engineering or humanities and social sciences.

The engineering-science committee feels that certain problems require further consideration:

1. Virtually all of the curricular material is a new synthesis. In some areas such as chemistry/physics this can proceed in straightforward fashion. In others, such as systems engineering, much information must come from the front lines in industry. Special consultant teams provide one possibility.

2. The curriculum recommended is essentially monolithic, with all courses interrelated in some fashion. How is the problem of unsatisfactory course mastery to be solved?

PROPOSED PROGRAM

The engineering-science committee offers a single program of broad courses. This program was evolved by the joint effort of Harvey Mudd science faculty members and the engineering consultants, and should help in the selection of the Harvey Mudd engineering faculty. Realistically, actual course content and approach will depend on the specific teacher involved; but also, realistically, course objective and curriculum interrelation should be stated as a matter of policy.

The attached chart depicts the organization of the curriculum by subject matter areas and years. Because the actual courses are for the most part new or recast, an indication of approach, topical content and suggested teaching emphasis is essential to an understanding of the curriculum. Broadly speaking it is suggested that:

1. the scientific orientation be achieved chiefly by scientists teaching science courses in the first two years. This is a reversal of a national trend but is believed feasible (and hence desirable) at Harvey Mudd because of the promising liaison between science and engineering faculties. The engineer recognizes a broad pertinent physical science area and its subdivision into departments may or may not be desirable. A common Science Laboratory would appear to promote desirable unification.

2. instruction in the engineering sciences should include the subject matter of:

   Mechanics of Solids and Fluids
   Nature and Properties of Materials
   Transfer and Rate Processes
   Thermodynamics
   Electrical Fields and Circuits

   A strengthening of the engineering science area can be achieved by presentation of the engineering sciences within a framework which recognizes the essential purpose of the engineering sciences as distinguished from the basic sciences. This distinction, in a few words, is that the objective of the engineering sciences is to provide experience with the *formulation* of components of engineering systems which call for analysis using scientific principles. This formulation calls for the construction of a much different kind of model than that used by the scientist.

It is the basic introduction to the main activity of the engineer which is to produce an optimum conceptual model or design of a real system. Without this experience in the formulation of real problems which require knowledge of the engineering sciences, there can be but little penetration into the realm of engineering design or systems analysis.

A science and engineering science senior year elective sequence be provided to permit and require the student to specialize and penetrate rapidly from the broad base achieved thus far in his unified curriculum. Elective sequences will depend upon the interests and special talents of the engineering staff. As a general rule the elective should involve engineering material, although depending upon special student interest, further special work in science or mathematics might satisfy the penetration requirement.

3. a systems engineering experience be provided through a unified course which includes laboratory work and design problems required each semester. In the first two years this serves as a general education for all students and provides a basis for choice of engineering as their career. In the last two years, culminating in an intensive project, the student confronts the engineering of systems of increasingly broader scope. It is in this course sequence that the student unifies and integrates his knowledge. In this sequence engineering methodology should be stressed quite apart from the acquisition of new technical subject matter. This methods work can begin with an identification of engineering systems, both discrete and continuous, with examples drawn from a variety of physical environments. It continues with formulation and solution of engineering problems, adequate for a senior year treatment of the design of engineering systems, involving feasibility, performance, producibility, reliability and cost considerations. This latter course should be taught by an engineer who actually has had personal experience with such activity. This senior course can consist of a required core the first semester and a design elective the second semester. It is important that this design elective not be just another technology elective. Choice will come from electrical, mechanical and chemical areas.

4. mathematics be required through five semesters with the aim of more coverage and at the same time more penetration than is customary for engineers. This can only be accomplished through considerable pruning of example and primary attention to the

fundamentals. The science and engineering courses must be relied upon to provide application and drill.

5. humanities and social studies receive like emphasis in the 32 semester hour allocation and be broadly related to engineering as a career objective. This suggests the relevance of self understanding and communication, value systems and implications of decisions over the short and the long haul. Engineering, as the "art of the possible to satisfy man's desires" is itself interwoven with elements of the humanities and social studies. It is suggested that overt ties be established by participation of the HSS staff in the senior engineering internship lab, including joint project work.

Because of the industrial and graduate school destination of graduates it is suggested that the California Engineer-in-Training examinations be administered to all at the close of junior and senior years and the Graduate Record Examination to all during the senior year.

Engineering-Science Committee:

DeForest L. Trautman, Chairman

Graydon D. Bell

J. Arthur Campbell

Robert C. James

Joseph W. McCutchan

James L. Meriam

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Robert R. White

Roy A. Whiteker

SAMPLE PROGRAM FOR ENGINEERING AT HARVEY MUDD COLLEGE

		MATHEMATICS (15 or 18)	HUMANITIES and SOCIAL STUDIES (32)	SYSTEMS ENGINEERING		SCIENCE (26)		
Freshman	16	3	3	Problems and Laboratory (17)	2	Science Lab 2	Chemistry 3	Physics 3
	16	3	3		2	2	3	3
Sophomore	16	3	3		2	2	Chem/Phys 3	ENGINEERING SCIENCE (26) 3
	16	3	3		2	2	3	3
Junior	16	3	3		3	3		7
	16	Mathematics or SYSTEMS ENGINEERING AND DESIGN (9 or 12) 3			3	3		7
Senior	16			7	3	Design Elective 3		Science or Eng'g. Science Elective (penetration) 3
	16			7	Senior Project 3	3		3

ROLES OF PHYSICS AND CHEMISTRY IN THE EDUCATION OF ENGINEERING STUDENTS

August 5, 1958

OBJECTIVES

1. To investigate the nature of the universe with primary emphasis on interpretation of experimentally observed natural phenomena in terms of generalizations or theories.
2. To study elementary applications of these fundamental concepts in several fields.
3. To apply to physical systems the skills and methods of reasoning learned concurrently in the mathematics courses.
4. To base problem-solving on experiments which stem from thoughtful initial analysis of the nature of the problem.
5. To familiarize each student with basic technics of observation, measurement, collection and systematization of data, and decision making.
6. To provide a fundamental knowledge of the component parts and operations of which engineering systems are made.

TEACHING METHODS

1. Parallel, well-coordinated courses covering areas large enough not to be fragments, but small enough to cohere and allow a logical growth in the student's knowledge.
2. Special attention to the unity of the physical sciences with parallel treatment from differing viewpoints but avoidance of redundancy.
3. Close cooperation in laboratory planning with possible joint laboratories to combine the best features of both points of view to given problems.
4. Emphasis on lecture and laboratory experiments which present problems whose solutions are unknown to the students.
5. Quantitative approach throughout with major emphasis on the application of mathematics to problem-solving and theorizing.
6. An ever increasing degree of independent work by the student, especially in the laboratory.
7. Combination of the microscopic and macroscopic interpretation of the behaviors of complex systems.

TWO YEARS' SEQUENCE IN PHYSICS

I. Mechanics of Solids

A. Kinematics of a point
Displacement, velocity, acceleration, particle paths, relative motion.

B. Kinetics of mass points
Mass, momentum, force, work, potential energy, kinetic energy, force fields, static stability (free body diagram), dynamic stability, conservative systems, friction, dissipative systems, constraints.

C. Kinetics of discrete particle systems
Angular momentum, impulse, moment of a force, degrees of freedom, center of mass, center of gravity, phase space.

D. Kinetics of rigid bodies
Moment of inertia, principal axes (translation of axes of rotation).

E. The real world
Elasticity (stress-strain relations, Young's modulus, shear modulus, bulk modulus), plasticity.

II. Fluid Mechanics

A. Hydrostatics
Velocity, acceleration, mass distribution, mass conservation, continuity equation.

B. Hydrodynamics
Bernoulli's equation.

C. The real world
Viscosity, fluid elasticity.

III. Heat

Statistical mechanics, gas laws, temperature scales, Zeroth law, heat a form of energy, First law, nature of a system (forms of heat transfer: conduction, radiation, convection), Second law (entropy).

IV. Vibratory Motion and Waves

Simple harmonic motion, three dimensional waves (interference, diffraction).

V. Electricity

Maxwell's equation (interaction of static charges and fields of moving charges and fields of accelerated charges and fields), conditions on continuity of charge, interactions of charges and fields in matter (static: polarization, permittivity, etc.; conductivity, hysteresis), energy storage (capacitance, inductance), transmission and radiation of energy (circuits).

VI. Atomic Physics

Elementary kinetic theory, electronic structure of atoms, particle-wave theory, solid state physics, nuclear physics.

TWO YEARS' SEQUENCE IN CHEMISTRY

First Semester:

Complexity of nature, various points of view and study, interpretations of properties in terms of molecular-atomic structure. "Fundamental" particles, nuclei, atoms, electron energy levels, periodic table, stoichiometry, chemical equations (mass, charge, energy balance). Molecular structure, interatomic forces (ionic, covalent, dipole, H-bond, van der Waals, repulsive), change in electronic energy levels from isolated atoms to condensed phases. States of matter, gases (disorder, simple kinetic theory, Maxwell distribution, ideal and non-ideal systems), liquids (surface effects, disorder), crystals (order, surfaces, packing effects, directed bonds), phase equilibria (stability ranges, escaping tendency, temperature and concentration effects, ideal and non-ideal systems). Experimental base in actual systems used throughout with many lecture and laboratory experiments.

Second Semester:

Chemical equilibria (dynamic, competitive), introductory quantitative treatment to simultaneous equilibria, homogeneous and heterogeneous systems, acid-base (new phase, weak electrolyte, complexion), oxidation-reduction, half-reaction potentials, effects of temperature, concentration, catalyst. Rates of reaction, control, temperature, concentration, catalyst, contact. Mechanisms of reactions. Organic chemistry, polymers, biochemistry. Descriptive chemistry of individual elements and compounds supplies examples throughout.

Third Semester:

Stoichiometry. The trend toward equilibrium. Description of material systems. Choice of variables. Microscopic and macroscopic views. Pres-

sure, temperature, volume, units and dimensions. Equations of state. Internal energy, enthalpy, heat content. Kinetic theory. Elementary quantum and statistical theory of energy levels (electronic, rotational, vibrational, nuclear, translational, molecular, condensed phase). Potential functions and interatomic forces. Distribution function. Entropy, free energy. (Most of the illustrative material up to these last two topics will be from the gaseous state.) Classical thermodynamic equations. Homogeneous and heterogeneous equilibria (1, 2, 3, ---n components), phase rule. Steam table (?).

Fourth Semester:
Liquids (surface tension, viscosity, momentum transfer, fluid flow), crystals (determination of structure, simple group theory, crystal forces and energy levels). Rates of chemical reaction (order, molecularity, absolute reaction rate, simple reactions, concurrent reactions, consecutive reactions, reverse reactions, steady state, determination of reaction mechanisms). Electrochemistry (limiting laws, conductance, interionic forces, electric cells, potentials, electrolysis, reversible-nonreversible systems). Surface chemistry (adsorption, heterogeneous catalysis).

Second Year Science Laboratory (22 weeks of short experiments, 8 projects):

Equipment building technics (always in connection with apparatus construction). Rough sketches, layouts, glass working, soldering, welding, simple machine shop practice, ordering.

Types of measurements (always in connection with work on a given system). Moments of inertia, pressure, volume, temperature, heat capacity, enthalpy, entropy, free energy, fluid flow rate, heat flow rate, electric current, voltage, resistance, capacitance, inductance, magnetic and electric fields, optical interference, wave lengths, spectra, density, vapor pressure, boiling point, melting point, surface tension, viscosity.

Possible experiments. Construct and test: thermocouple, thermistor, vapor pressure apparatus, vacuum pressure gauge, potentiometer, Wheatstone bridge, amplifier, dielectric constant outfit, calorimeter, flowmeter.

Possible systems measurements. Maximum flame temperature, crystallization rate, electrolytic conductivity, chemical or phase equilibria, phase diagrams, chemical rates of reaction, corrosion, radiochemistry, nuclear physics, HETP, molecular weights, molecular or atomic energy levels, heats of reaction, thermal transpiration, heat balances, spectroscopy (nuclear to radio), stress.

Possible projects. Design, construct, test, and report on a piece of equipment. Purify and determine accurately the properties of a chemical. Measure the temperature of the sky as a function of time, weather, etc.

MATHEMATICS IN THE ENGINEERING CURRICULUM

August 5, 1958

OBJECTIVES AND METHODS

The primary emphasis is to be on ideas and understanding. The curriculum is designed around basic concepts, rather than being a succession of topics. This is done so as to obtain wide coverage, without using the survey technique. The concepts are to be made interdependent so that there will be as much continuity of treatment as possible.

Applications and illustrations are chosen primarily to strengthen understanding, both of the mathematical ideas and methods and of the techniques of application. As seems appropriate, further applications will be introduced by the other science departments. The topics to be included are dictated by the needs of the other departments and by the needs of mathematics majors.

Mathematics is to be taught from a mathematical viewpoint, with applications regarded as pedagogical devices to bring about understanding of the concepts and of the techniques of application. For this purpose, it is important that students learn to use the process of logical deduction and that they acquire the ability to set up problems and to analyse and carry out solutions. They should also learn to appreciate the power of mathematical methods and the beauty and elegance which these methods can have.

HMC students are carefully selected and are well prepared in mathematics. However, it is recognized that there will also be great differences in their mathematical ability and interest. There will be a "fast section" formed from students who seem able and willing to cover five semesters' work in four. It is hoped that this will maintain the mathematical interest of the better students and give them opportunity to elect an extra semester of mathematics.

Some topics will be given only sufficient introduction to demonstrate the nature and value of the particular mathematical methods involved, with specific emphasis on possible applications. The students will then have the background necessary to recognize possible applications of these methods and to study and extend this knowledge when needed. There will also be opportunity to elect other mathematics courses which build on the concepts of required courses.

COURSE CONTENT

I. *First Semester*
Rate of change.

Definition of function and functional notation
Average rate of change
  Average velocity and acceleration
  Equation of a line
Instantaneous rate of change
  Definition
  Techniques of evaluation (algebraic functions)
  Tangent lines, etc.
Relation between average and instantaneous rates of change
  Mean value theorem and differential approximations
Transcendental functions
  Exponential and logarithmic
  Trigonometric
Introduction to partial differentiation
First order differential equations.
  $dy/dx = f(x)$ (velocity, acceleration, area, etc.)
  Other first order equations and applications

II. *Second Semester*
Geometric concepts and notation.
  Limits and continuity
    Some elementary topological ideas (continuity of transformations)
    Laws of limits (continuity of rational functions)
  Transformation of Cartesian coordinates (general quadratic and the conics as applications)
  Polar coordinates
  Vectors (definition, scalar product, applications — distance to a line)
Definite integrals
  Definition (and existence)
  Applications (math., physics, etc.)
  Techniques of evaluation
  Introduction to multiple integration

III. *Third Semester*
Set theory
  Abstract sets (logic, Boolean algebra, circuits)
  Probability and statistics
Linear processes
  Matrices (linear transformations)
  Linear programming and game theory (convex sets, matrices)
Approximation methods
  Solution of equations (algebraic and d.e.)
  Infinite series
  Statistical procedures

IV. *Fourth Semester*
- Rate of change of functions of several variables
  - Partial differentiation
    - Chain rule; total differential (mean value theorem); exact differentials
  - Directional derivative
    - Gradient, potential, normals, tangent planes
- Generalized definite integration
  - Tie-in with probability and statistics (measure)
  - Line integrals
  - Multiple integrals
    - Definitions and evaluations
    - Surface area (Green's and Stokes' theorems)
    - Cylindrical and spherical coordinates
    - Change of variables
- Higher order differential equations
  - Second order linear equations
  - Some examples of non-linear equations

V. *Fifth Semester*
- Fourier analysis and orthogonal functions
  - Fourier series and transforms
  - Other examples of orthogonal functions and their theory and applications
- Laplace transforms
- Complex variables
  - Cauchy-Riemann equations
  - Conformal mapping
  - Contour integration

VI. *Sixth Semester* (not required for all engineers).
- Further study of series, integration, and partial differentiation
- Special functions
- Partial differential equations

THE PLACE OF ENGINEERING SCIENCE IN THE CURRICULUM

August 8, 1958

OBJECTIVES AND METHODS

The objective is to provide training in science from the engineering point of view, building upon and extending the science work of the first two years. In this body of knowledge the student should be able to distinguish dogma, theory, and practice, and concentrate on theory. The teachers should be engineering scientists so that this body of knowledge

becomes a blend of science and engineering. There should be plenty of problem work, with attention to the identification of the system under study. The synthesis approach should be introduced by turning many of the analysis problems around. Lecture experiments and other learning aids should be employed, with complete knowledge of the concurrent experiences in the junior laboratory. Above all, this teaching-learning activity must build on the mathematics and science the student engineer is learning. A goodly portion of the subject matter in the ASEE "Report on the Engineering Sciences" (1958) will have been covered — and in the recommended manner — if the science and engineering staff establish the liaison which is possible in this small college with reasonably well-defined goals.

Laboratory work can be handled in several ways:

(1) divided up and attached to each engineering science course;

(2) combined into one unified engineering science laboratory in which the student may use his knowledge from the several courses;

(3) combined further with laboratory experiences in systems engineering and design, the continuing experience from the lower division.

A unified treatment has much in its favor because it focuses attention on the why of a (whole) system. The choice between (2) and (3) can be made, pedagogically, on the basis of providing design experience in contrast to emphasizing measurement and analysis experiments. Even with the engineering design and engineering science laboratories separate in principle, considerable interplay can exist by virtue of certain projects which involve the design of an experiment and a measuring apparatus, which is then actually used to determine a scientific quantity.

COURSE CONTENT

Sophomore Year

It is important that the student begin early to apply basic principles to real engineering systems. One possibility is to use actual apparatus, such as a pump, an electric motor, a refrigerator, using whatever principles from science are appropriate to a thorough understanding of behavior. Several fields could be involved, e.g., for the electric motor, electric circuits and fields, heat (cooling), mechanics (effect of moment of inertia during transient conditions), etc. Another possibility is to delve more completely into electricity circuit theory as a method and tool, or thermodynamics as it bears on engineering systems in general.

Junior Year

One approach is to organize the subject matter into three core courses which will bring together all the engineering science material covered by the ASEE report. Possible course content might then be:

Materials: The subject matter in the ASEE report not already covered at sufficient depth from the sections on "Nature and Properties of Materials" (pp. 38-39), "Electrical Sciences" (p. 33, items B and C), "Thermodynamics" (p. 29), certain parts of "Transfer and Rate Processes," of "Mechanics of Fluids," and "Mechanics of Solids" (pp. 6-8). Some attention can also be given to materials resources: natural, synthetic and manufactured parts, including their producibility.

Energy: The subject matter in the ASEE report not already covered at sufficient depth from the sections on "Electrical Science" (p. 34, item II, Basic Concepts of Energy Processing), "Thermodynamics" (pp. 25-31), certain parts of "Transfer and Rate Processes," "Mechanics of Solids," and "Mechanics of Fluids." Some tying together of the various physical environments can occur under the topics of Resources (or origin) of Energy in its many forms, Storage (e.g., electrical, nuclear, chemical, inertial), Conversion (inter- and intra-environment), Transmission (all forms including radiation), and Control. (For an example of the handling of mixed systems see *Proceedings of the Institute of Radio Engineers*, July 1958, p. 1428: "On the Codification of Lagrangian Formulation.")

Information: The subject matter in the ASEE report not already covered at sufficient depth from the sections on "Electrical Sciences" (p. 34, Information Processing, Control of Energy, and Circuit Concepts), "Thermodynamics" (statistical concept of entropy), "Transfer and Rate" (circuit model and feedback), "Mechanics of Solids" and "Mechanics of Fluids" (equation of motion: topological concepts). Some tying together of the various physical environments can occur under the topics of Origin (resources): experiment (uncertainty, equivocation), perceptors, transducers, quantity; Storage: states of matter, circulating delay line, books; Conversion: logical transformations and decision making, filtering; Transmission (communication) and Control. The temptation may exist for this course to lean heavily toward circuits, feedback, servomechanisms, radio engineering, electronics, but should definitely be avoided; the analysis and processing of information is an engineering science — not an application. The contrast of Information with Energy (and Matter) must be made as basic to a full under-

standing of nature and function for later application by the engineer.

Senior Year Penetration Elective

Because of the high caliber of student and teaching at Harvey Mudd it should be possible to do a first-year graduate course such as Otto Smith's "Feedback Control Systems," especially since one of the basic purposes is exercising the student in penetration and learning on his own. Advanced work in science and mathematics may also be acceptable.

D.L.T.

SYSTEMS ENGINEERING IN THE HARVEY MUDD CURRICULUM

August 8, 1958

OBJECTIVES

The systems engineering portion of the program should help the student:

1. to see and deal with an engineering problem as a whole (not merely to solve some isolated part of the problem), whether it be the winding of an armature or the design of a freeway.
2. to acquire methodical approaches and good work habits in solving engineering problems: identification of problems, planning an attack upon them, and arriving at the most appropriate solutions.
3. to see the interrelationships and apply the facts and principles learned in all other parts of the program: physical science, mathematics, engineering science, humanities and social sciences.
4. to learn how to accomplish an engineering design with due regard to all relevant factors technical and social, e.g., measurements, graphics and communications, feasibility, producibility, reliability, cost and pay-off functions, human needs and social consequences, aesthetics, desirability and usage.

METHODS

The following methods are suggestive of procedures which might be useful.

1. The work might well be done in a laboratory setting, with field trips and visitors from industry supplementing campus facilities.

2. Problems presented might well vary from the broad one considerably beyond the student's ability to solve completely (used as a shock treatment) to a very specific problem such as the design of a screw or gear.

3. In general problems should progress from the relatively simple to more complex ones which introduce more and more relevant factors.

4. Problems might well be planned so that each emphasizes a somewhat different controlling factor, e.g., mechanical design, cost, materials, human limitations, graphical analysis, communication of ideas, political and social elements.

5. Problems should be planned by members of the various faculties: engineering, mathematics, physical science, humanities and social sciences. Instruction, then, would be given and papers read by members of the faculties which are most concerned because of the nature of the particular problem.

6. Studies on campus might well be supplemented by carefully chosen summer employment and perhaps by a summer community study project.

COURSE CONTENT

The actual problems chosen for the systems engineering sequence must depend upon the interests, training, and ingenuity of the staff at Harvey Mudd. The following are merely illustrations.

The design of an amusement park
The design and location of a freeway
The design and sale of a mechanical cotton picker or similar machine
The design and installation of a new automatic process
The design, installation, and sale of a control system
The communication of a recommended procedure to management and then of its implementation to a foreman
Evaluation of a patent as a technically sound investment

The development of a four-year sequence of the type described above is admittedly difficult. Its planning would demand a large share of the faculty's time, and a degree of cooperation among disciplines which is all too rare in American academic life. Undoubtedly there would be many trials, and not a few errors. But the rewards to the student of bringing to bear on a series of problems all the learning and experience of college life should compensate for the energy necessarily devoted to the effort. Harvey Mudd College can make an unusual contribution to engineering education merely by viewing the student's educa-

tion as a whole, by confronting him in college with situations which can teach him to use professionally all of his knowledge, scientific, technical, humanistic and social.

S.W.C.

THE PLACE OF THE HUMANITIES AND SOCIAL SCIENCES IN SYSTEMS ENGINEERING

August 8, 1958

In interpreting this report particular emphasis should be given to the integrating factors. Although they are implicit in the entire program, some of them need perhaps to be made more explicit.

In considering the part of the curriculum devoted to the Humanities and Social Sciences, it must be clearly understood that the entire program is considered essential to the education of engineers; it is not an engineering curriculum with a dose of liberal arts added for the purpose of putting more polish on the final product. The intention is that in the engineering core, which constitutes the heart of the program, the student will draw upon his Humanities and Social Science background just as he draws on Mathematics, Physics, and Chemistry for the solution of his engineering problems. More accurately, engineering problems are so conceived as to extend well beyond strictly technical considerations.

A student might at the beginning be asked to design a fairly simple mechanism — for example, a thermostat to operate within given limits of sensitivity. After working out the technical details he would go on to prepare drawings for use in production, estimate the market for the product, and calculate costs. This process might conceivably lead him to conclude that while the gadget was technically feasible, it could not be manufactured at a profit. He should also consider where the product should be made in the light of the location of markets and materials, labor supply, transportation, etc.

On a larger scale a student could be asked to design an express highway between given points. Here he would have to consider not only engineering cost factors but social problems: the effect on communities along the route, the relocation of population, aesthetic considerations — the list could be extended indefinitely.

Viewed thus, the role of the Humanities and Social Sciences in the Harvey Mudd curriculum is more important than the number of hours specifically allocated to courses in these disciplines. As the program now stands, the Harvey Mudd student gives more of his time to formal courses in the Humanities and Social Sciences than is customary at

American engineering colleges. Beyond that, moreover, in his engineering work the student will draw directly upon concepts, ideals, and information from the Humanities and Social Science area and will also be led to explore parts of this area not included in his formal courses.

It does not follow that the Humanities and Social Sciences at Harvey Mudd should be aimed at providing material for use in solving problems in systems engineering. To do so would be to defeat the purpose of this part of the program. We wish to make the Harvey Mudd student a broadly educated individual. In addition, the Humanities and Social Sciences should bear the same relationship to the engineering core as do Mathematics, Physics, and Chemistry. That is to say, in each field the student should acquire a grasp of fundamental concepts and methods and become aware that these are essential components of the problems he will be called upon to solve.

The members of the committee agree that no formal mechanism for achieving this integration can or should be proposed at this point. The problem is one for the Harvey Mudd faculty to work out. The fact that the staff will be small provides a favorable setting for the development of a genuinely integrated program, provided the individual members understand and sympathize with the objective proposed in this report.

J.B.R.

HUMANITIES AND SOCIAL SCIENCE IN THE HARVEY MUDD CURRICULUM

July 29, 1958

This is a preliminary report on the discussions, conclusions and problems of the humanities-social science committee of the Harvey Mudd College Summer Curriculum Study.

OBJECTIVES

Harvey Mudd College states the reason for its existence in a few sentences in its *Bulletin.*

> New frontiers of science are being explored at an unprecedented rate, and our technology is applying science to the creation of industries that were undreamed of a few years ago. . . By the time you graduate from college, there will be industrial processes in use which we do not even know today, and many of our present technologies will have changed almost beyond recognition. The increasing knowledge and control we have of our physical sur-

> roundings is changing the way of life of peoples everywhere, economically, politically, and socially. There will be need for all the scientists and engineers the United States can hope to train for many years to come.

It follows, therefore, that Harvey Mudd students must do more than learn the existing fund of factual knowledge. They must master the principles and methods of science upon which much change is based; develop their intellectual capacities and apply them critically and rigorously to diverse problems; grow not as narrow specialists but as men ready and able to specialize; and, finally, exercise their imaginations creatively.

These goals are appropriate to more than the students' technical training. To quote again from the *Bulletin:*

> The College was founded in the belief that a special need exists for physical scientists and engineers sufficiently broadly trained in the social studies and the humanities to assume technical responsibility with an understanding of the relation of technology to the rest of our society.

If they are to discharge such responsibility in a free society, students must understand the crises of the modern world and respond to them with the intellectual penetration, analytical ability, and values adequate to the solution of present and future problems.

The humanities-social science committee has recognized a national movement in engineering education by adopting as valid objectives for a program those stated in 1940 and again in 1945 by committees of the American Society for Engineering Education. These aims, in amended and abbreviated form, can be stated in this way: study of the humanities and social sciences should help the student:

1. to understand our social organization and the influence of technology on its development;
2. to analyze intelligently problems involving social and economic elements;
3. to express thoughts logically and lucidly;
4. to understand the nature and significance of literature and the fine arts;
5. to develop moral, professional, and social concepts essential to a satisfying personal philosophy;
6. to develop an inquiring mind and a creative spirit;
7. to find lasting interest and pleasure in these pursuits.

METHODS OF ACHIEVING OBJECTIVES

The humanities-social science committee has tried of course to keep in mind the particular position of Harvey Mudd College. It agreed very early in its deliberations that the College was right in creating its own staff to teach the humanities and social sciences rather than relying on sister colleges. It believes that all members of this staff should be in one administrative department.

For a few years at least, the staff will probably be engaged in developing new courses, with fresh and significant approaches. Since the staff will be spending an unusual amount of time and energy on teaching, the usual standards of appointment and promotion might well need modification during that period.

The committee has agreed on the following principles for planning a program to carry out the objectives of the College in the humanities and social sciences.

1. *Required courses.* A substantial portion of the program should consist of courses required for all students. Approximately equal emphasis should be given to the humanities and social sciences. These courses might well involve considerable recasting of materials now found in traditional courses. In this case a carefully planned sequence in which each course depends upon preceding ones is desirable.
2. *Areas of concentration.* A significant part of the program should be devoted to elective areas of concentration (e.g., economics, history, literature, the fine arts). Here again approximately equal emphasis should be given to the humanities and the social sciences. There should be, however, a limited number of areas; within each a student should not elect at random but should be required to take a carefully planned group of related courses. The great majority of these courses should be taught by the Harvey Mudd faculty.
3. *Nature of the courses.* No course should be taught with only the scientist's or engineer's job in mind. Every course should emphasize fact, practice, and theory in the field of its concern. Only then can it be liberalizing rather than technical.

The committee feels that certain problems still require further consideration:

1. How can more materials from such fields as life science, psychology, and foreign languages be integrated into the program? How much attention should be given to civilizations other than that of the West?

2. Exactly what types of common required courses should be developed? Should they be standard courses in traditional disciplines or interdisciplinary courses of the survey type?
3. What should be the proportion of time allotted to required courses and to courses in the elective areas of concentration?
4. Can there be a successful integration of technical and social-humanistic work through the medium of a senior project?

PROPOSED PROGRAMS

The humanities-social science committee has not attempted to formulate a single program for Harvey Mudd College, recognizing full well that the teaching faculty must finally develop its own program. This preliminary report offers, therefore, the following suggestions for possible curricula.

STUART W. CHAPMAN, *Co-Chairman*
DONALD G. STILLMAN, *Co-Chairman*
WILLIAM H. DAVENPORT
IREDELL JENKINS
ORME W. PHELPS
PHILIP RIEFF
GEORGE WICKES

SUGGESTED PROGRAM IN HUMANITIES AND SOCIAL STUDIES

S. W. CHAPMAN

FIRST SEMESTER		SECOND SEMESTER	
First Year:		Introduction to Humanities and Social Studies	3 hrs.
Introduction to Humanities and Social Studies	3 hrs.		
Second Year:		Literature	3 hrs.
Introduction to Humanities	3 hrs.	Functions of Government	3 hrs.
Economic Analysis	3 hrs.		
Third Year:		Free Elective	3 hrs.
Art and Music	3 hrs.	Elective in area of concentration	3 hrs.
Group Behavior	3 hrs.		
Fourth Year:		Senior Project	3 hrs.
Elective in area of concentration	3 hrs.	Individual in Modern Culture	3 hrs.
Individual in Modern Culture	3 hrs.		

Introduction to Humanities and Social Sciences: course basically historical in approach; introduction to nature of life, man, and culture; historical periods and emphasis to be determined in considerably part by needs of later courses; much reading in "great books."

Economic Analysis: national income analysis; value theory.

Literature, Art, and Music: historical approach minimized; discussion of purposes of writer and artist; materials and techniques available; ways of using them to achieve a work of art.

Functions of Government: functions, conflicting philosophies of purpose, organization in relation to functions and purposes; clashes of interest groups, etc.

Group Behavior: psychological in approach, but using materials from sociology, anthropology, etc; discussion of different types of groups, religious, political, economic, etc.

Free elective: to be taken in area of concentration or not.

Electives in area of concentration: related courses in area chosen by student.

Senior Project: project involving technical and social elements, supervised by members of both faculties.

Individual in Modern Culture: philosophical in approach; discussion of modern problems emphasizing values and goals of individuals and groups in contemporary culture.

SYNOPSIS OF PROGRAM IN THE HUMANITIES AND SOCIAL SCIENCES FOR HARVEY MUDD COLLEGE

IREDELL JENKINS

FIRST SEMESTER		SECOND SEMESTER	
First Year:		Appreciation, Analysis, and Communication.	3 hrs
Appreciation, Analysis, and Communication	3 hrs	Intellectual and Institutional History.	2 hrs
10 hrs			
Intellectual and Institutional History	2 hrs		
Second Year:		Psychology.	3 hrs
Doctrines and Institutions of Contemporary American Culture	3 hrs	Art and Literature	3 hrs
9 hrs			

Third Year:		Theory of Law and State.	3 hrs
Ontology and Epistemology.	3 hrs	Comparative Contemporary Cultures.	3 hrs
9 hrs		*or*	
		Economic Theory and Analysis	3 hrs
Fourth Year:		Elective.*	3 hrs
Value Theory.	3 hrs	Elective* or Senior Project.§	3 hrs
12 hrs			
Elective.*	3 hrs		
40 hrs			

*The electives and senior project are to be in one of the three general areas of Economics and Management, Literature, or Philosophy of Science.

§The senior project will be permitted only to students that the faculty feels to be mature enough to profit from its freedom.

I. General comments:

1. The sheer presentation of fact, whether past or contemporary, is to be minimized. Emphasis should be placed on ideas and principles through which facts are explained, and on the techniques and practices through which facts are controlled. The purpose of the program is to extend and refine the students' direct participation in life: this calls for a cultivation of intellectual skills rather than an accumulation of information.

2. So far as possible, the work should be organized around certain basic concepts, which will be exemplified and analyzed. Such concepts are those of Nature, Life, Mind, Community, Methodology (or Techniques).

II. Comments on specific courses:

1. Appreciation, Analysis, and Communication. Emphasis on skills requisite to understanding and expression. Reading; seeing and listening. Communication, written, oral, and graphic. Appreciation and intepretation of art-works. Analysis of written material. Principles of logic and rhetoric. Problems of semantics.

2. Ontology and Epistemology. Analysis of the character and structure of Reality, or Being, as such; and of the methods of

inquiry, and modes of knowledge, through which this is grasped. Emphasis on phenomenal complexity of the world, and on the concepts that have been found necessary to explain this. Examination of alternative theories of Reality. Such a course is indispensable to any basic work in science.

3. Value Theory. An analysis of the contents and conditions of human well-being, or happiness. Examination of the needs and drives that animate human behavior; of the stages through which these move to completion; of the ends of life; of the formation and criticism of purposes; of the necessary constituents of human realization; of the problems and conflicts with which life confronts man. Aims at an ability to anticipate the difficulties and decisions of life, envisaged as a process of value-seeking and value-realization.

4. Theory of Law and State. An analysis of the origins and functions of political organization; of the different values that political activity must take account of; of the problems it encounters; of the varied forms it takes. Effort should be directed toward developing an abstract conceptual schema in terms of which different theories can be analyzed and compared. Account of American constitutional theory and its principal contemporary alternatives.

5. Intellectual and Institutional History. Examination of some of the principal stages and epochs in the development of the Western cultural tradition. This will deal both with abstract ideas and with social and human institutions. Familiarize students with the more important contributions and phases through which the tradition they inherit has been created. Emphasis on Time, Development, Alternatives that man and culture confront, Values chosen and sacrificed or compromised. Enable students to stand on the shoulders of their predecessors and so to move effectively toward the future.

6. Doctrines and Institutions of Contemporary American Culture. The preceding courses brought immediately up to date.

7. Comparative Contemporary Cultures. Examination and evaluation of principal cultural traditions that are different from our own. Make students aware of the legitimately different beliefs and values of other civilizations. Cultivate a spirit that is at once critical and tolerant.

PROPOSED CURRICULUM IN HUMANITIES AND SOCIAL SCIENCE

ORME W. PHELPS

Objectives of the Proposal. — This proposal has two major objectives:

1. maximum choice (the widest possible range of options to students);
2. maximum practicability, in the matters of staffing, scheduling, and the transfer of credits.

It will be argued that if these two objectives can be realized the result will be a really significant educational experience in the humanistic-social science area for the maximum number of students at Harvey Mudd College. This conclusion rests on the following presumptions:

a. Students — even those students who have elected to do their major work in a technical field — differ in background, tastes, and interests. No prescribed course of study in the tremendously broad areas of the humanities and the social sciences will fit all of them or can even be sure of engaging their attention.

b. The faculty in the humanities and the social sciences will be a small, "supporting" staff. If it is to be strong, some attention will need to be given to disciplinary specialities. As a practical matter, this can be done better in the framework of a "distribution/concentration" program, using course titles and course content similar to those met with in the best liberal arts colleges throughout the country, and with some possibility of advanced course work for all.

The Proposal (assuming 42 semester hours of work in a four-year course.)

1. a 9-course "distributional requirement" spread across 6 subject matter fields, and
2. an "area of concentration" selected from one of the subject matter fields, in which the student would take either 4 or 5 courses *plus* his distributional requirement in that field, to make a total concentration of 6 or 7 courses (18 to 21 semester hours). A sample program in Economics, displayed schematically, would be as follows:

	Labor Economics
(Read horizontally for "distribution requirements")	Money & Banking
	National Income
(Read vertically for "area of concentration")	Accounting
	Statistics
Freshman Eng., Psychology, Philosophy, Lit. Hist.	Prins. of Economics
Literature Hist.	Prins. of Economics (Social Science)

I think it feasible for the faculty at Harvey Mudd College to offer at least four (possibly more) areas of concentration, two in the social sciences (Economics, Political Science), and one each in Literature and History (with Philosophy, Psychology, and Management as possibilities, depending on staff). These would be, in effect, humanities and social science "minors" with a relatively broad distribution core.

DESIGN OF THE SOCIAL SCIENCES-HUMANITIES PROGRAM

PHILIP RIEFF

Soc-Hum I (6)*

("Science and Religion": development of the western scientific spirit, and of the western religious spirit. Readings in Greek science and philosophy. Readings in Christian theology.)

(Total college faculty and administrative personnel)

Soc. I (6)

("Social Systems": the nature of social organization, with special reference to the shift from feudal to capitalist organization.)

(Soc. faculty)

Hum. I (6)

("Culture in Transition": four major periods of western culture; the southern renascence, the northern, Victorian culture, the 'American renascence.')

(Hum. faculty)

Soc-Hum II (6)*

("Modern Personality and Modern Culture": the 'problem' of civilization, as seen in terms of the question of personal identity. Readings from both the social sciences and the humanities.)

(Soc-Hum faculty)

Social Science Field of Concentration (6)**

I. Economics
   a. — — —
   b. — — —
   c. — — —
II. Industrial Sociology

Humanities Field of Concentration (6)**

I. Aesthetics
   a. Industrial design
   b. Introduction to art
   c. — — —
II. — — — — — —

* One lecture, two discussion periods

** The student may elect to take all 12 hours in one or the other field of concentration. Once having chosen his field and approved subfield (s), his specific course requirements are established by the appropriate faculty.